φ and ω decay modes ratios

A.Stavinskiy,ITEP,Moscow

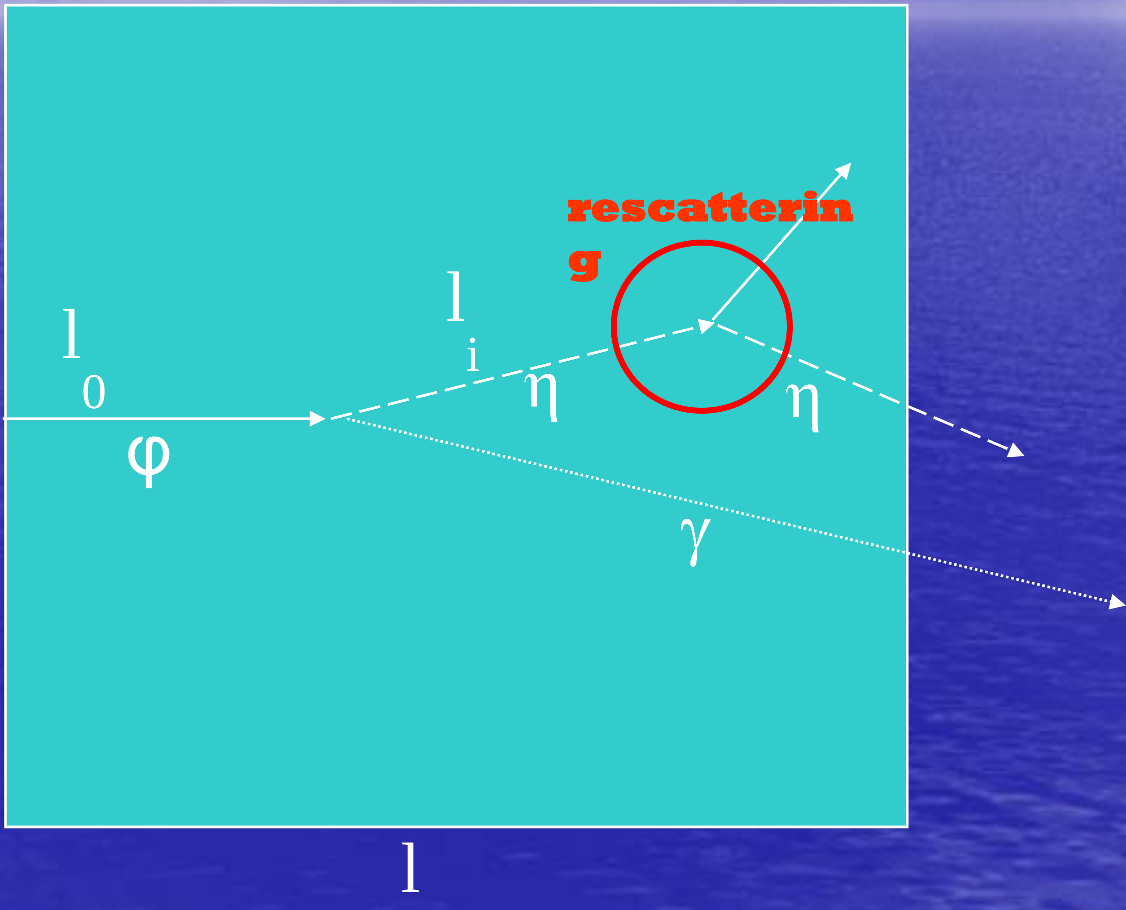
- Physical motivation
- Sensitivity (toy model estimate)
- Possibility (real data)
- Conclusion

Physical motivation

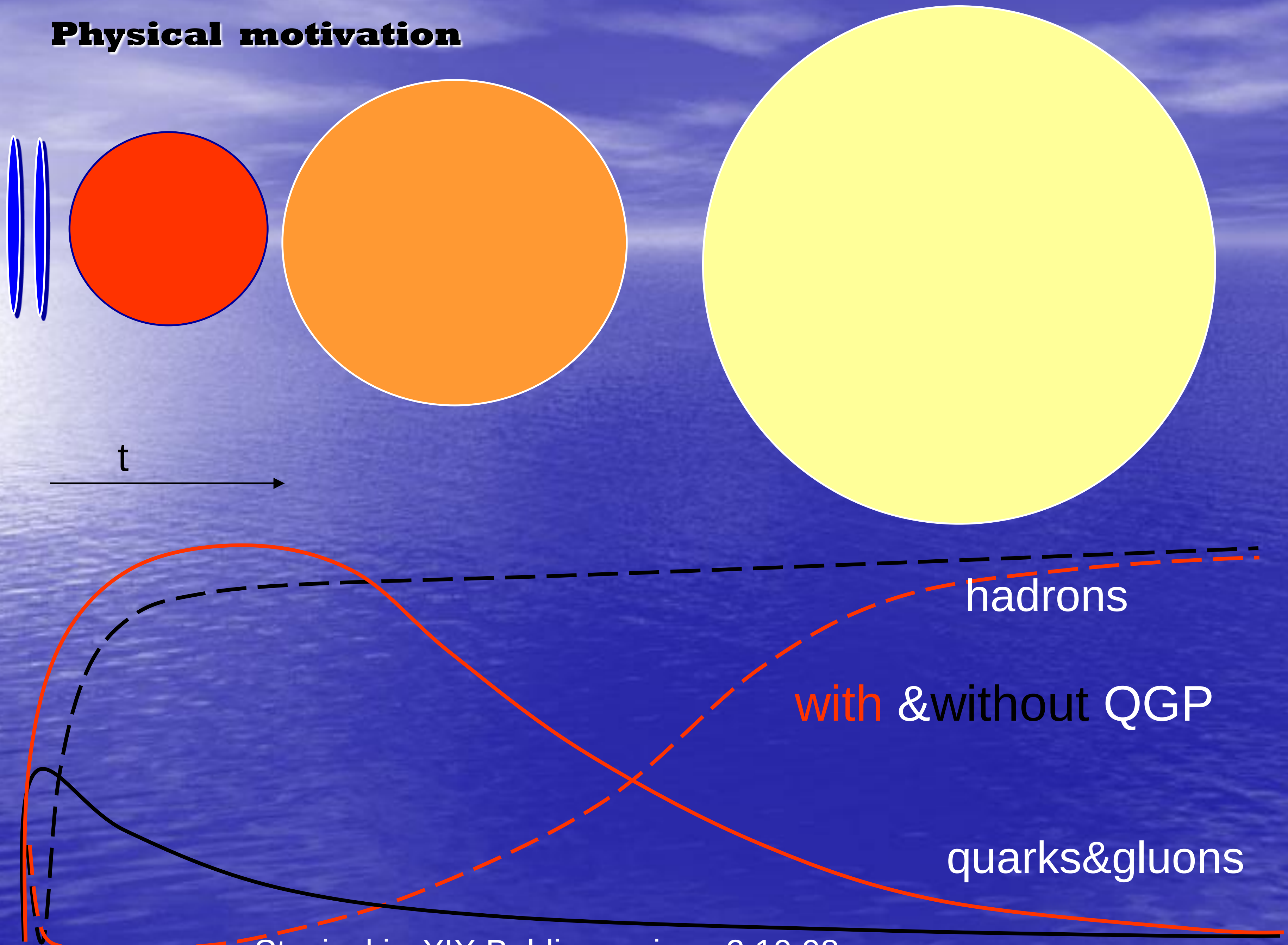
If resonance decays before kinetic freeze-out ⇒
Possible rescattering of hadronic daughters ⇒
Reconstruction probability decrease for hadronic mode

Possible applications:

- **K^{*0}/K may reveal time between chemical and kinetic freeze-out**
- **Branching ratio between different decay modes may be sensitive to reaction mechanizm (not only due to possible mass modification)**

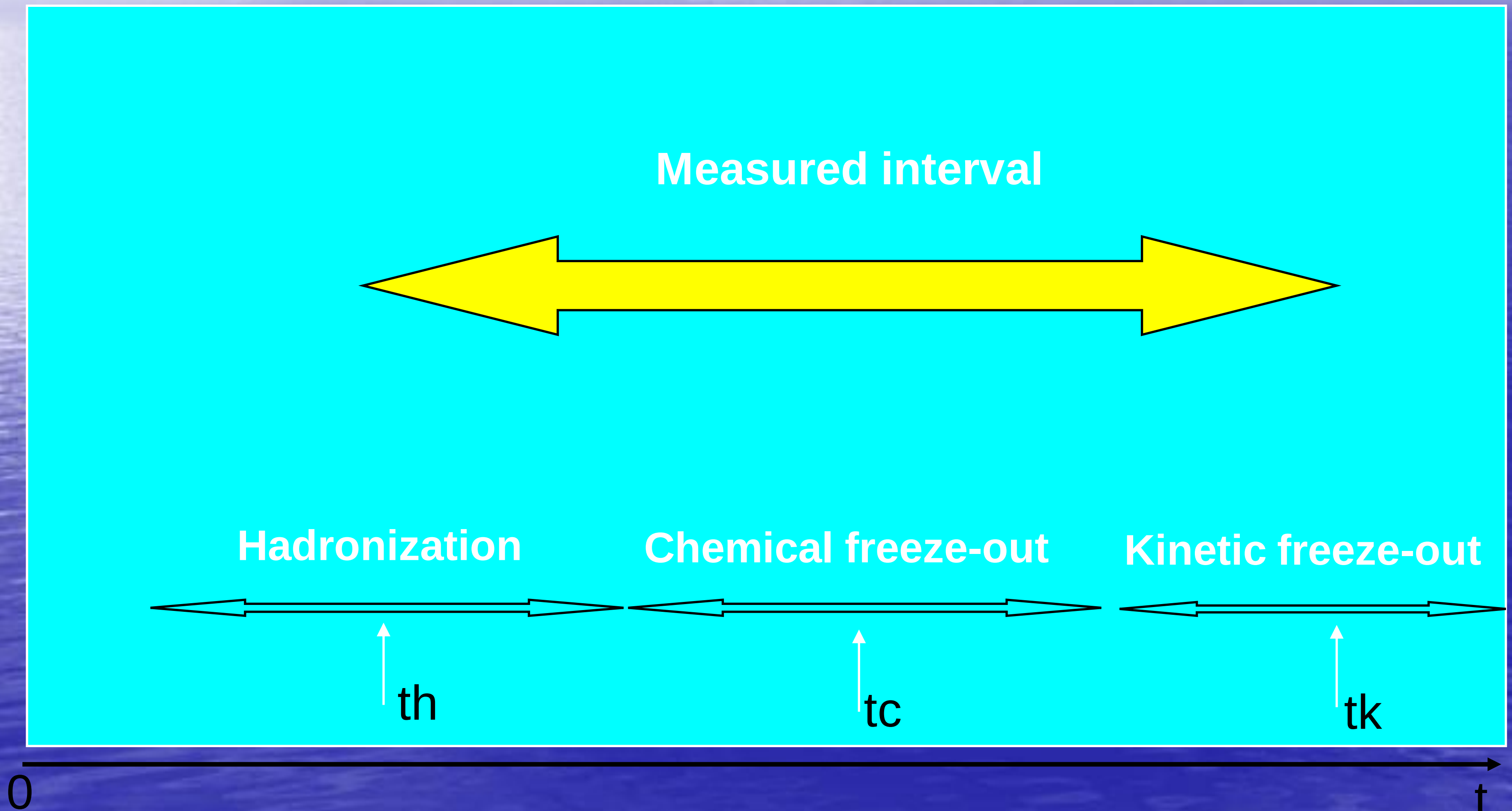


Physical motivation



Physical motivation

Decay modes ratios – new source of information



Physical motivation

Decay inside interaction region $c\tau < 50$ fm

Combinatorial background for hadronic modes $c\tau > 5$ fm

Possible candidates:

$\omega(782)$ ($c\tau = 23$ fm)

$\varphi(1020)$ ($c\tau = 44$ fm)

Physical motivation

Branching ratio between different decay modes may be changed due to rescattering or (for example) due to possible mass modification

- **Solution-three (or more) modes**

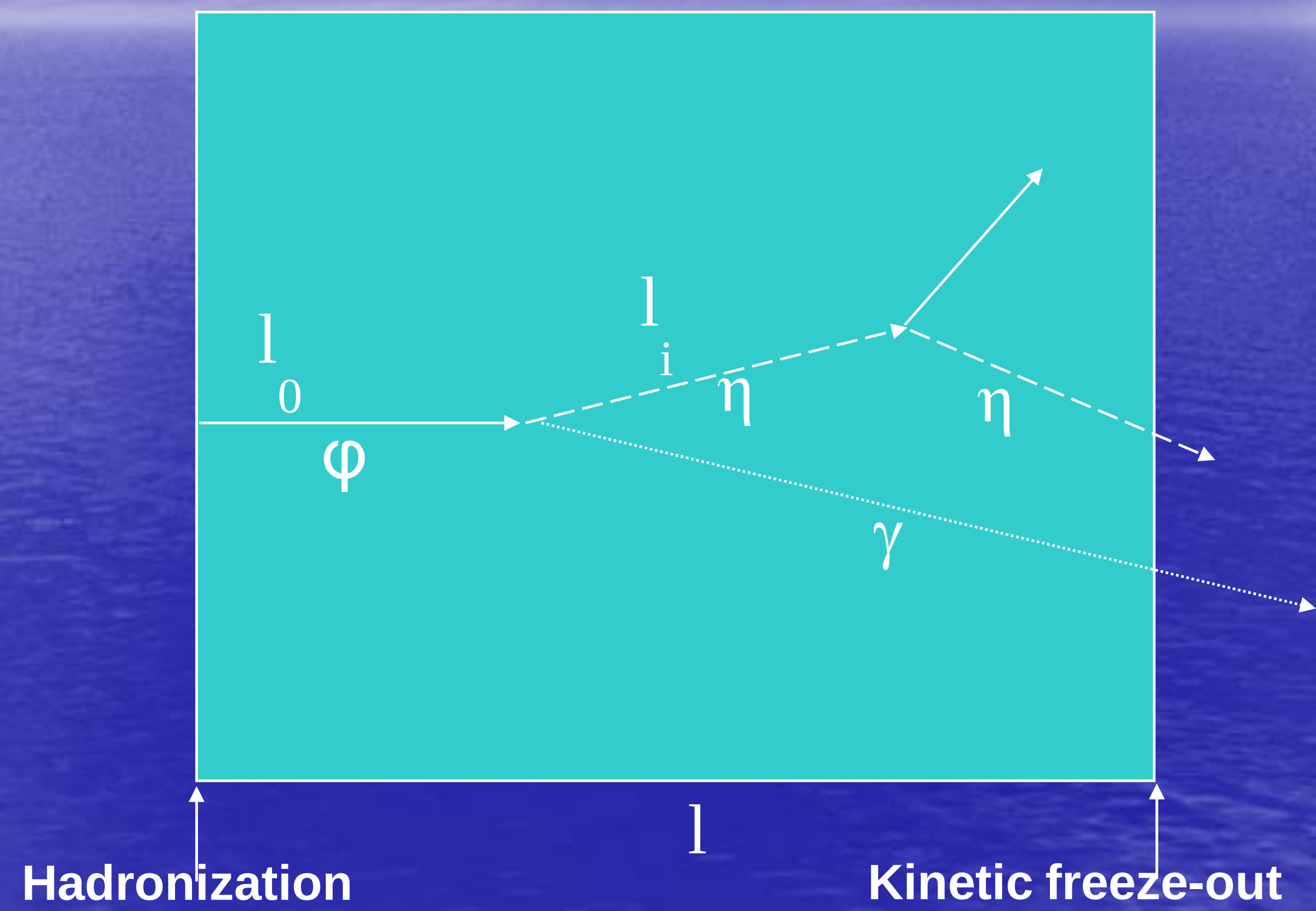
$\omega(782) \rightarrow \pi^+ \pi^- \pi^0$	B.R. 0.89
$\omega(782) \rightarrow \pi^+ \pi^-$	B.R. 0.017
$\omega(782) \rightarrow \pi^0 \gamma$	B.R. 0.089
$\omega(782) \rightarrow e^+ e^-$	B.R. 0.000072
$\varphi(1020) \rightarrow K^+ K^-$	B.R. 0.49
$\varphi(1020) \rightarrow \eta\gamma$	B.R. 0.013
$\varphi(1020) \rightarrow e^+ e^-$	B.R. 0.000297

Sensitivity

$l_0 \sim c\tau\beta/\sqrt{(1-\beta^2)} \sim$
$\sim(\beta=1/3$ for this estimate$)\sim$
$\sim$15fm(for φ)&8fm(for ω)

Toy Model

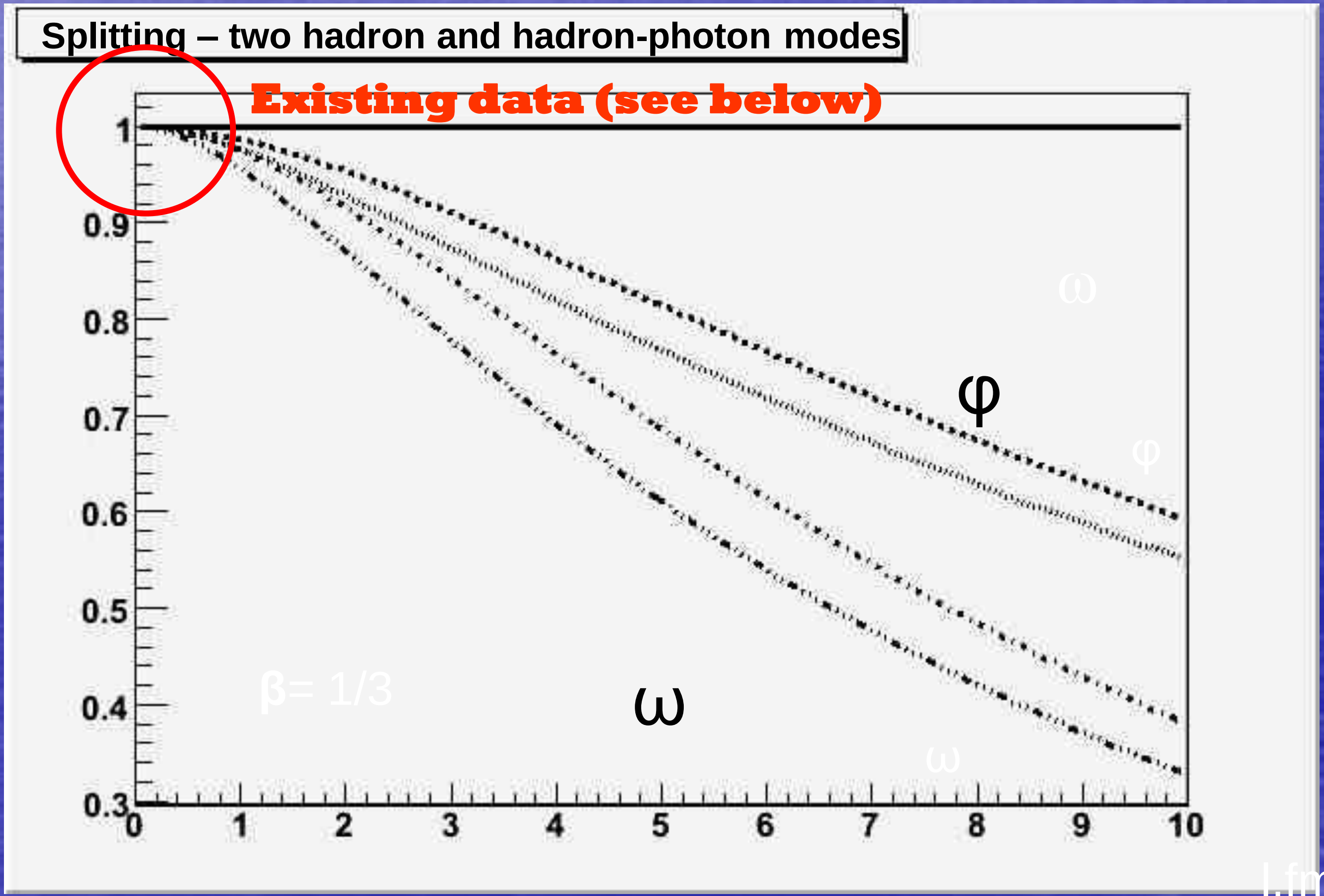
$l_i \sim$2fm for any hadron & 1fm for any pair of hadrons



Sensitivity Possibility

Estimate Results

- Relative supression of photonic & hadronic modes with respect to leptonic mode



l -decay products trajectory length within matter

l_0 -decay length

l/l_0~3-5 ?

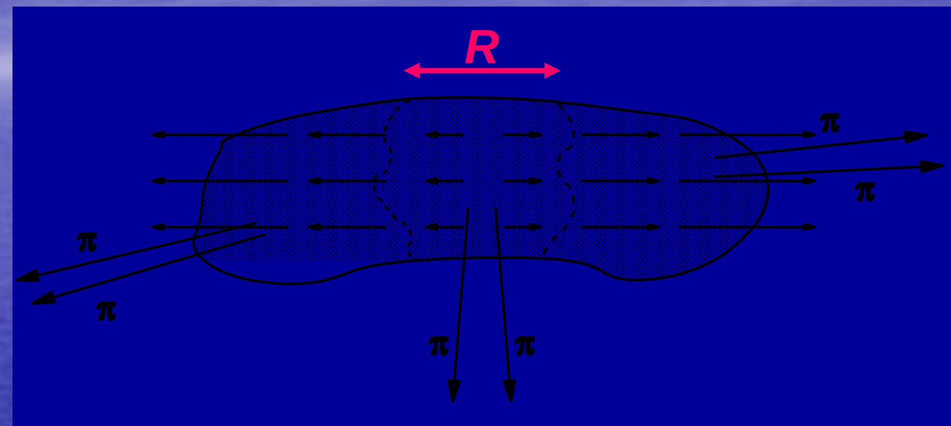
Sensitivity

1) l~30fm ALICE ?

l > R where r~ 5-7 fm

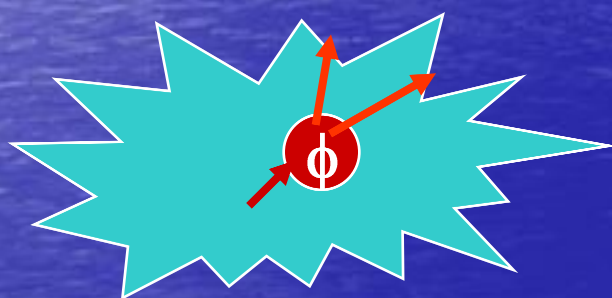
space-momentum correlations ⟶ R- length of homogeneity

Femtoscopy

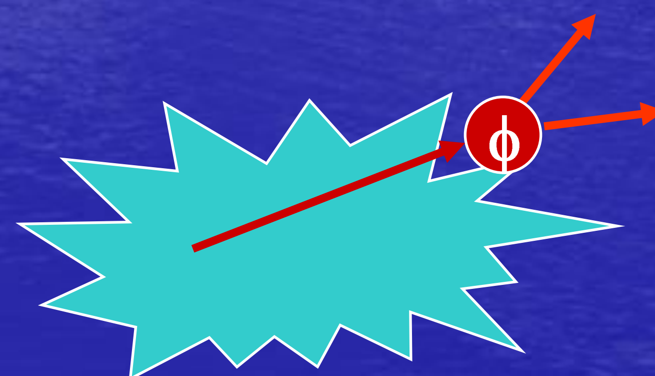


2) v~0.1c CBM ?

Fix target experiment



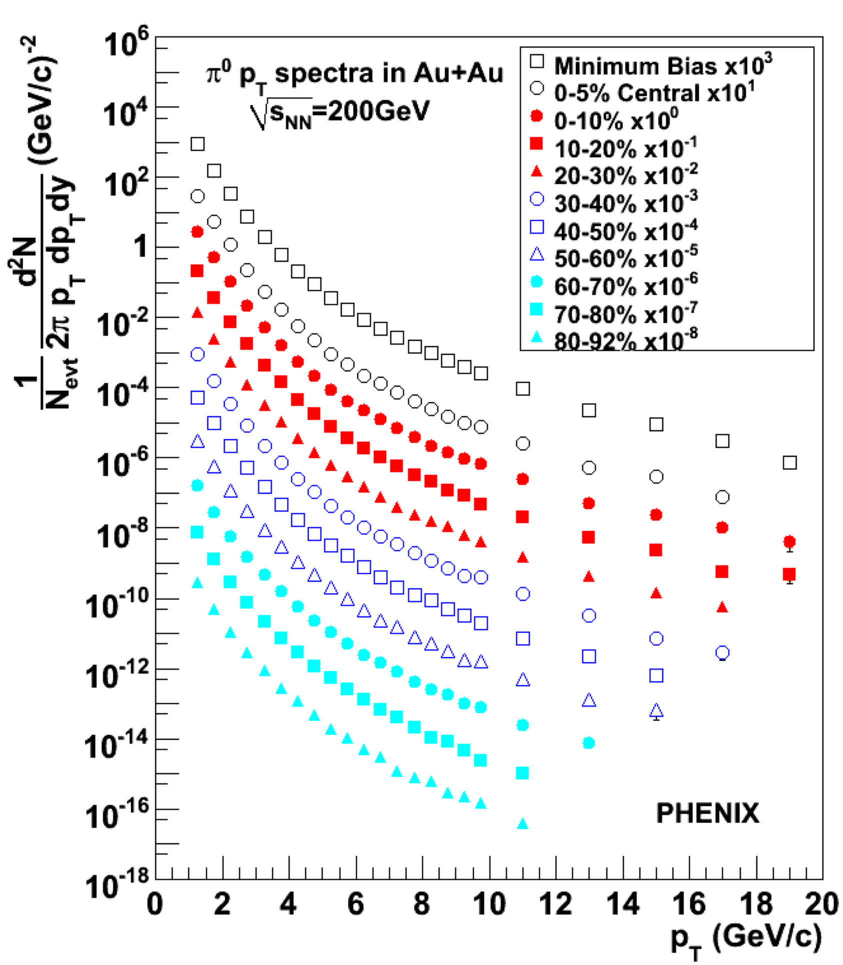
Low p

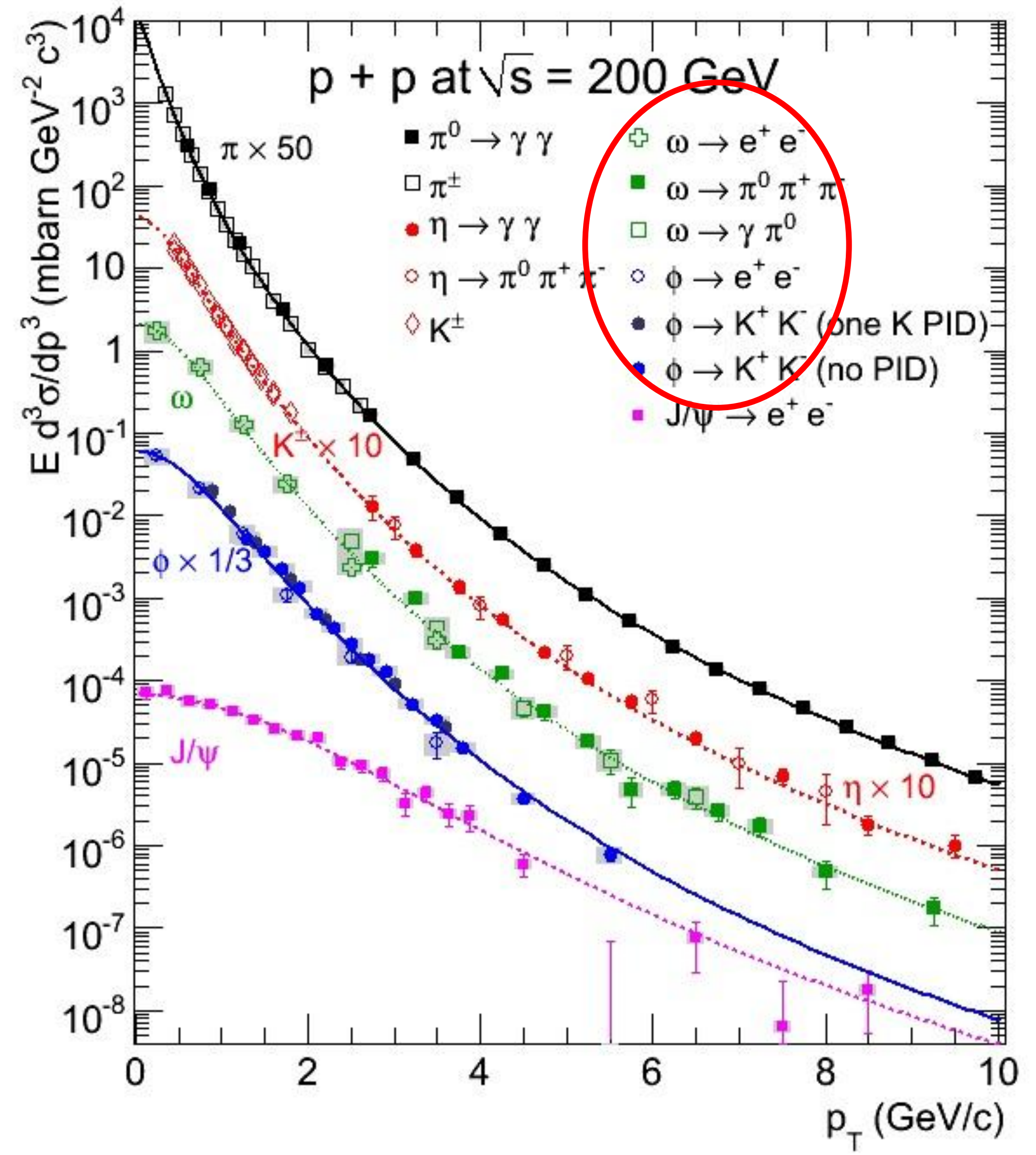


High p

Low momentum mesons tend to decay inside the hot/dense matter

Possibility





π^0 Au+Au 200 GeV (Run 4)

arXiv:0801.4020

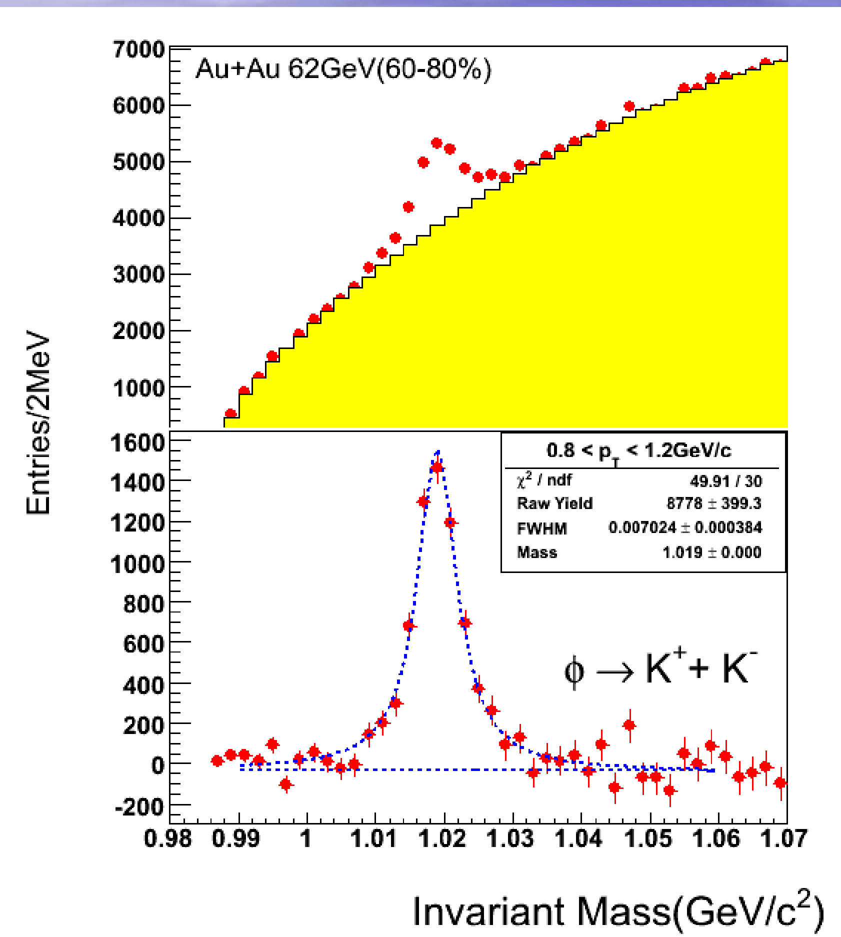
Source: Vladislav Pantuev ,PHENIX for XIX Baldin seminar, Dubna 2008

Possibility sources:

P.Fachini(BNL,SQM2007)

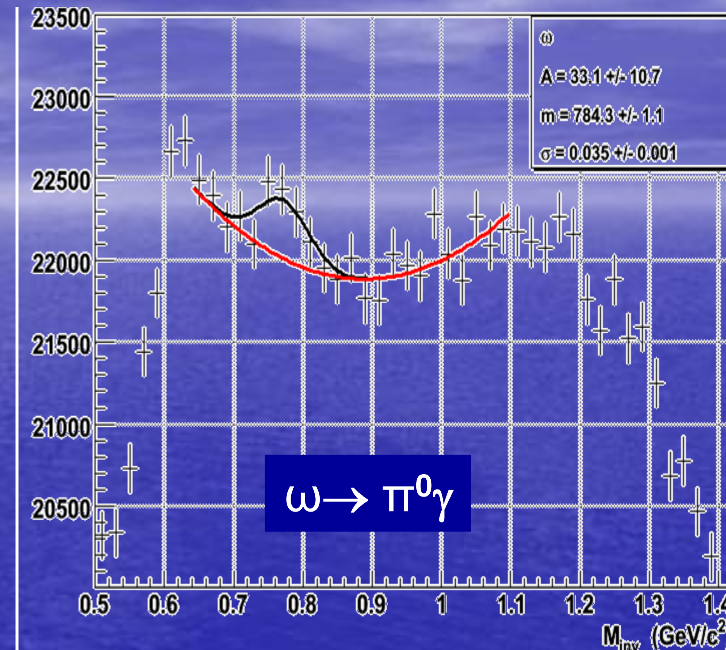
Y.Nakamiya(Hiroshima , QM 2008)

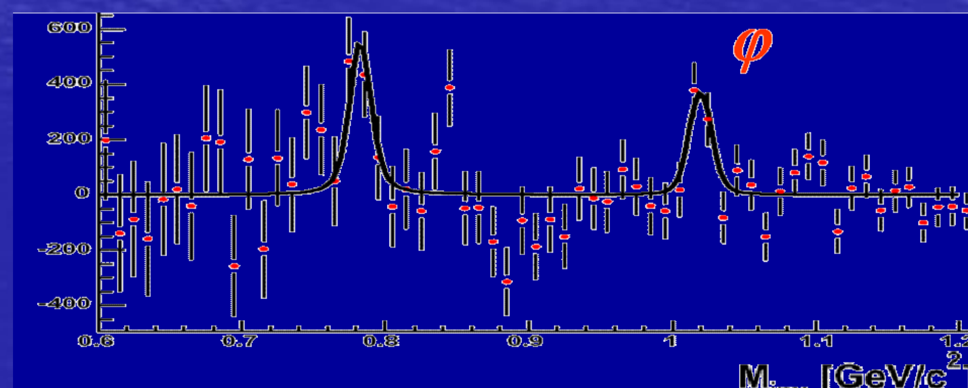
STAR



PHENIX

Au+Au $\sqrt{s_{NN}}$ = 200 GeV



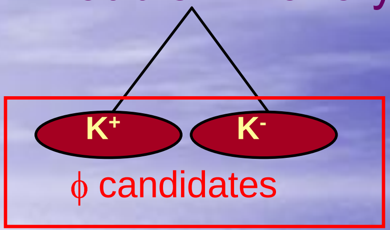


$\phi \to e^+e^-$

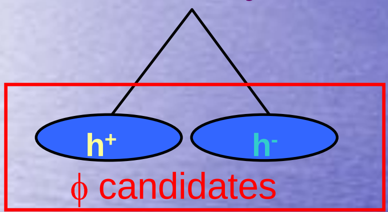
PP collisions: Consistency between $\phi \to K^+K^-$ and $\phi \to e^+e^-$

Possibility

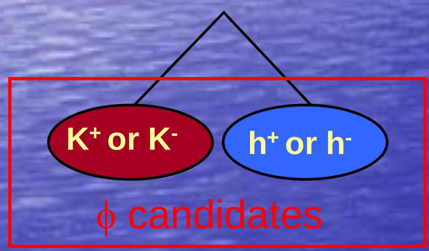
Double ID analysis

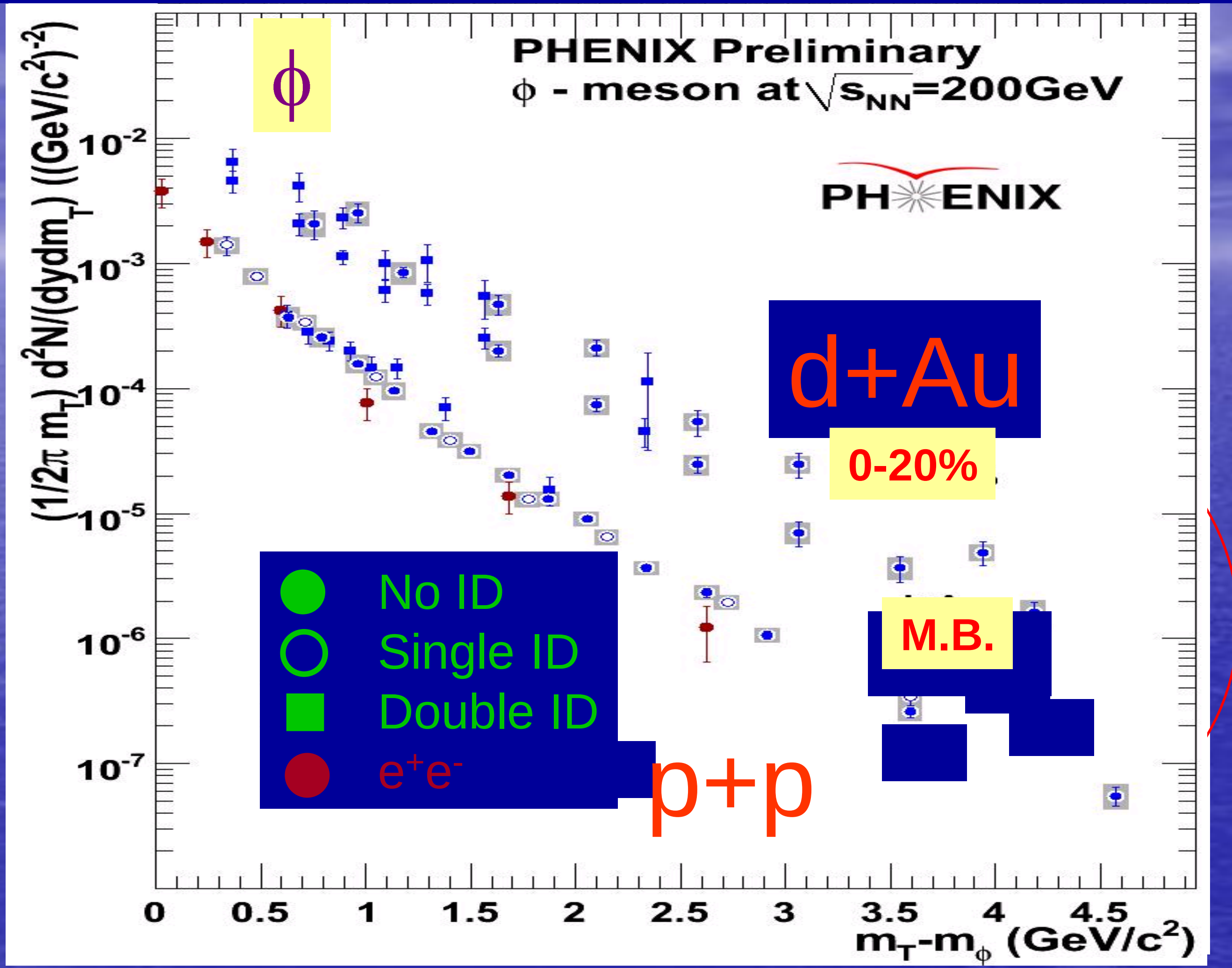


no ID analysis



Single ID analysis



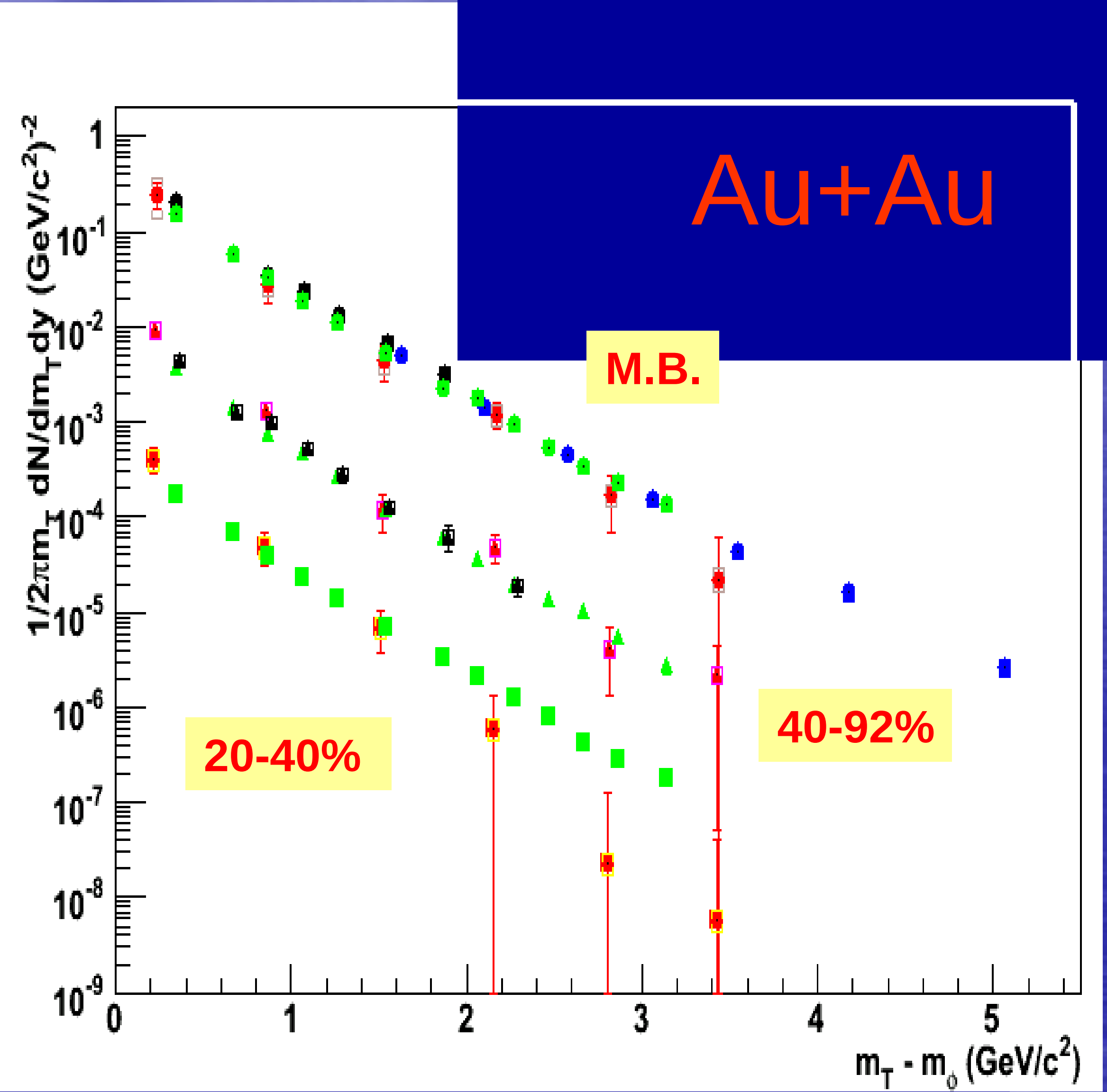


In p+p, spectra of e^+e^- and K^+K^- show reasonable agreement!

Possibility

Spectra comparison between

$\phi \rightarrow e^+e^-$ and $\phi \rightarrow K^+K^-$



- $\phi \rightarrow e^+e^-$ AuAu MB
- $\phi \rightarrow e^+e^-$ 20-40% x 10^{-3}
- $\phi \rightarrow e^+e^-$ 40-92% x 10^{-1}
- $\phi \rightarrow K^+K^-$ AuAu MB (no PID)
- $\phi \rightarrow K^+K^-$ AuAu MB (double PID)
- $\phi \rightarrow K^+K^-$ AuAu MB (PRC72 014903)
- $\phi \rightarrow K^+K^-$ 20-40% x 10^{-3} (double PID)
- $\phi \rightarrow K^+K^-$ 40-92% x 10^{-1} (double PID)
- $\phi \rightarrow K^+K^-$ 40-92% x 10^{-1} (PRC72 014903)

Errors are too large to make any clear statement about the comparison of spectra for $\phi \rightarrow e^+e^-$ and $\phi \rightarrow K^+K^-$.

Conclusion

- Decay modes ratios-new source of information
- Vector mesons – candidates for the study of the effect

To Do

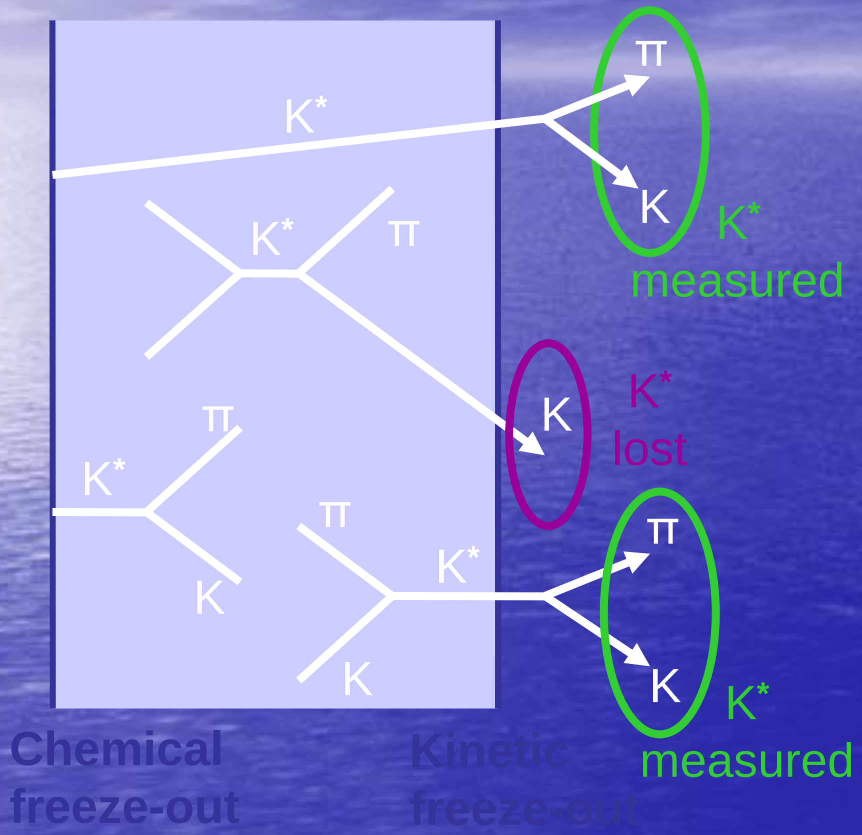
- To make calculations for the effect of interest within realistic model
- To create algorithm for photonic modes identification in AA interactions
- To check this algorithm for ALICE&CBM conditions with realistic simulations

Extra slides

- $\Phi \Rightarrow$ information early stages of the collision
- $\Phi \Rightarrow$ different production for hadronic and leptonic channels

S. Pal *et al*., Nucl.Phys. A707 (2002) 525-539

- $K^* \Rightarrow$ time between chemical and kinetic freeze-out

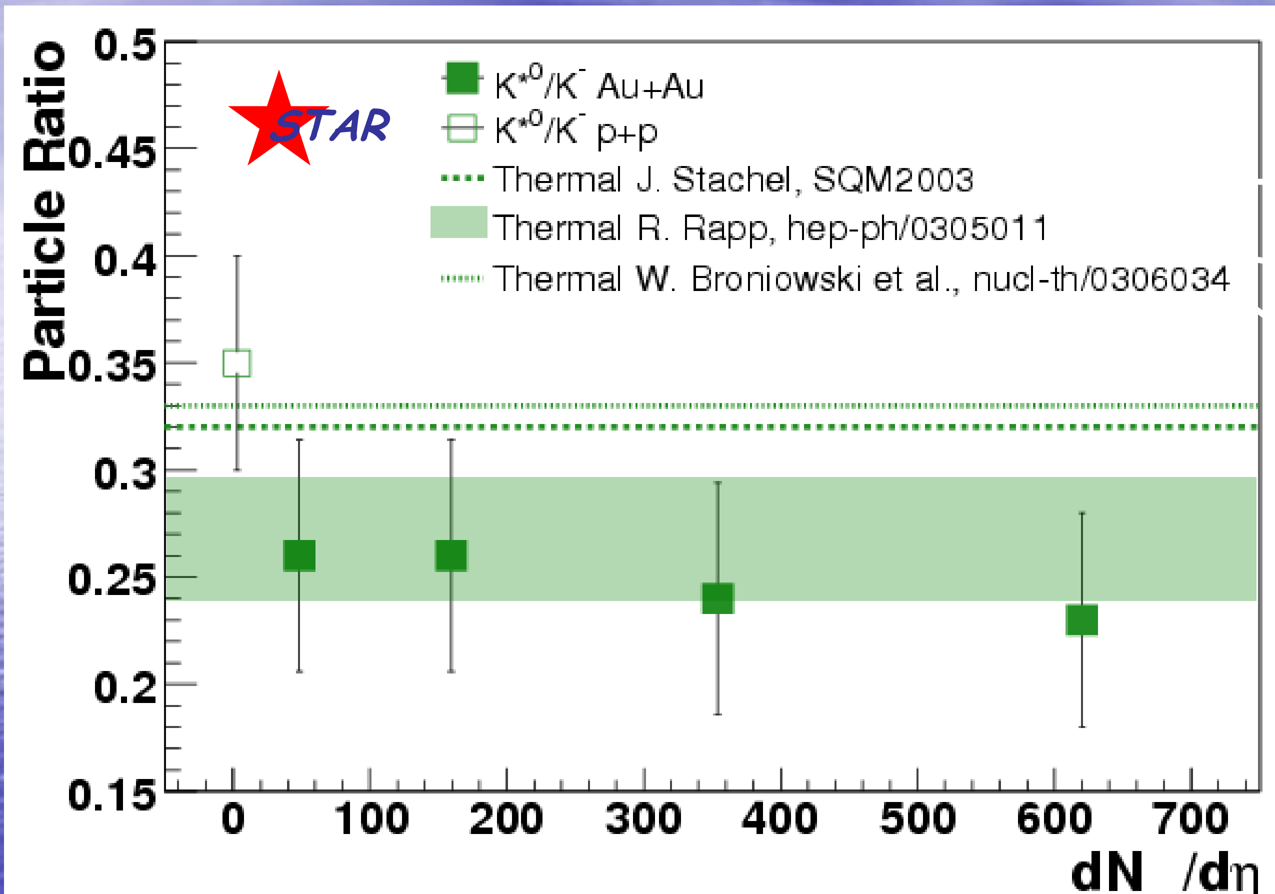


- If resonance decays before kinetic freeze-out $\Rightarrow$ not reconstructed due to rescattering of daughters
- K^{*0} ($c\tau$ = 4 fm) survival probability $\Rightarrow$ time between chemical and kinetic freeze-out, source size and p_T of K^{*0}
- Chemical freeze-out $\Rightarrow$ elastic interactions $\pi K \rightarrow K^{*0} \rightarrow \pi K$ regenerate $K^{*0}(892)$ until kinetic freeze-out
- K^{*0}/K may reveal time between chemical and kinetic freeze-out

P. Fachini

BNL,SQM2007

K* ⇒ Ratios



Chemical freeze-out

Kinetic freeze-out

Chemical = Kinetic freeze-out

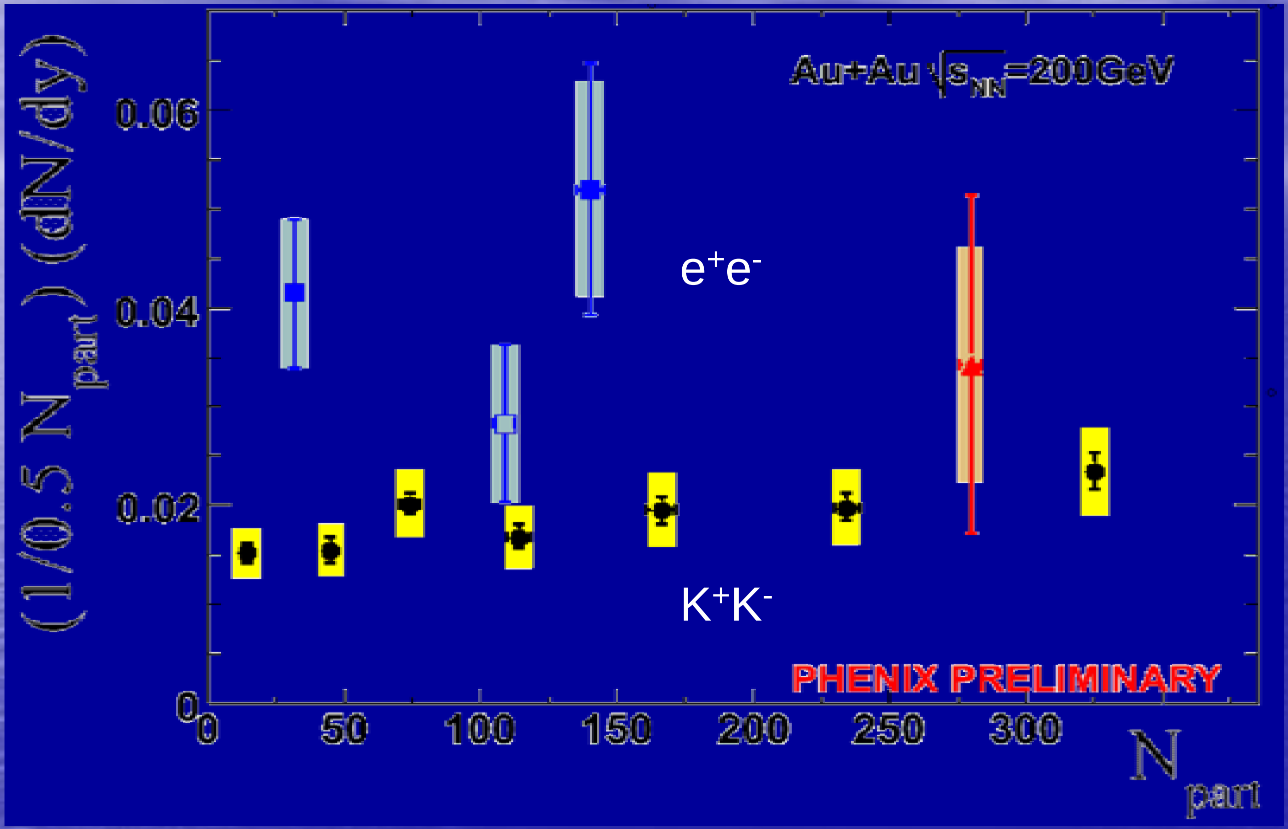
- K^*/K^- ⇒ p+p ratio reproduced by thermal model at chemical freeze-out ⇒ Au+Au reproduced by thermal model at kinetic freeze-out

Y. Nakamiya
Hiroshima University, Japan
for the PHENIX collaboration
QM 2008, India

Branching ratio between e^+e^- and K^+K^- may be sensitive to mass modification, since M_{phi} is approximately $2 \times M_K$.

–> Compare yields of $\phi \rightarrow e^+e^-$ and $\phi \rightarrow K^+K^-$

Φ Production $\Rightarrow$ K^+K^- and e^+e^-



- The leptonic channel yield is a little higher than hadronic channel
- More accurate measurement is required to confirm whether there is branch ratio modification

What is the difference?

- Modes absorbtion vs Mass modification
  - Standard mesons vs modified mesons
  - $\varphi \rightarrow KK$ & $\varphi \rightarrow \eta\gamma$
- Modes absorbtion vs K/K^* ratio
  - Reference- Lepton modes vs thermal model
  - Hadronization stage vs equilibrium stage
- Modes absorbtion vs both other approaches
  - Internal cross-check - 3 modes

Real σ_{MN} in matter can differ from that in free space

- ω photoproducton on nuclear targets (ELSA)

M.Kotulla et al., ArXiv: nucl-ex/08020980

$\sigma_{\omega N}$ ≈ 70 mb (in nuclear medium, $0.5 < P < 1.6$ GeV/c)

$\sigma_{\omega N}$ ≈ 25 mb (in free space - the model calculations)

photoproducton on nuclear targets

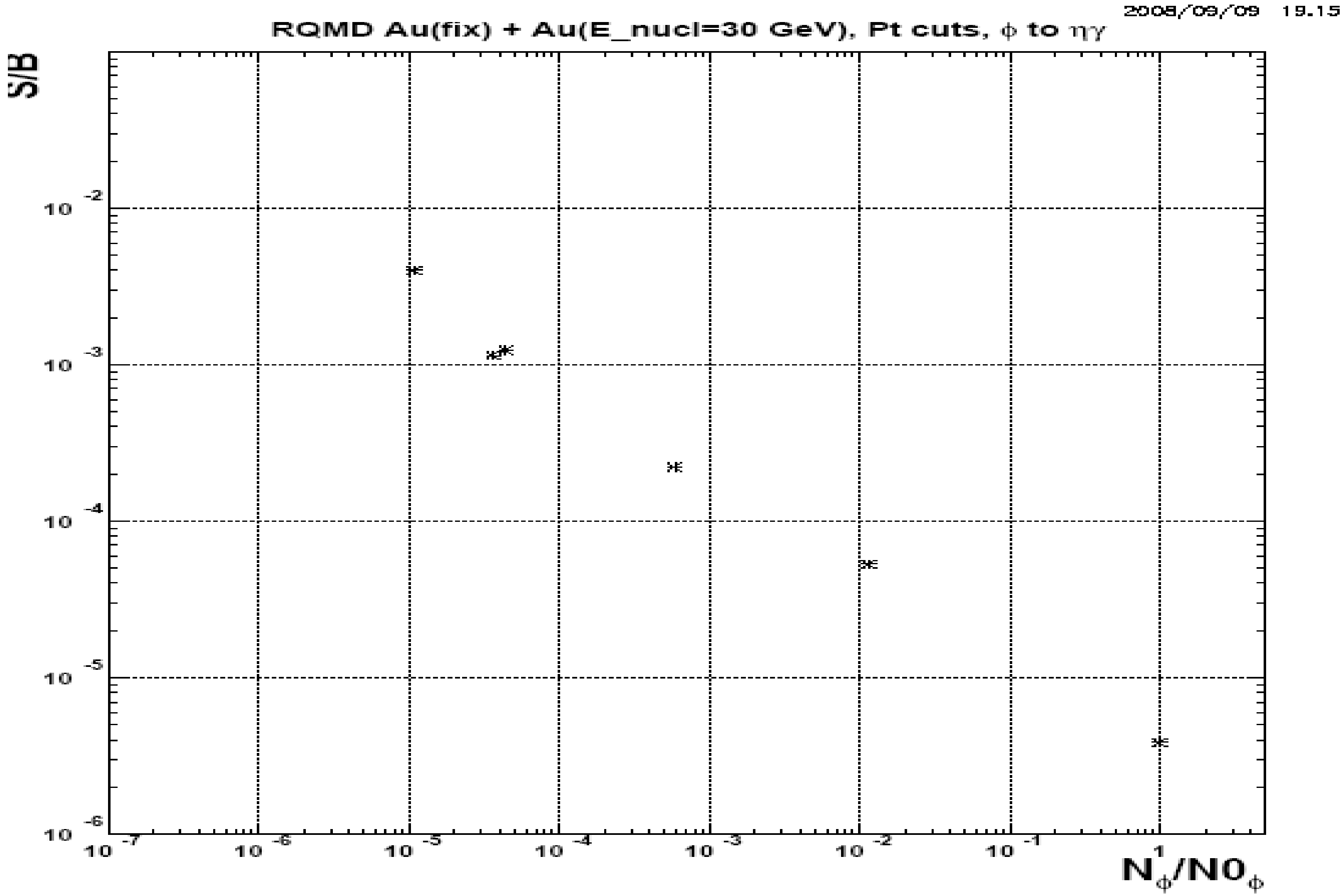
- ϕ photoproducton on nuclear targets

T.Ishikawa et al., Phys.Lett.B608,215,(2005)

$\sigma_{\varphi N} = 35 \pm 14$ mb (in nuclear medium)

$\sigma_{\varphi N} \approx 10$ mb (in free space)

"φ-puzzle"


2008/09/09 19.15
RQMD Au(fix) + Au(E_nucl=30 GeV), Pt cuts, ϕ to ηγ
S/B
10 -2
10 -3
10 -4
10 -5
10 -6
10 -7
10 -6
10 -5
10 -4
10 -3
10 -2
10 -1
1
N1ϕ/N0ϕ

Formulas

$$W_i = B_i * (\exp\{-l / l_0\} +$$

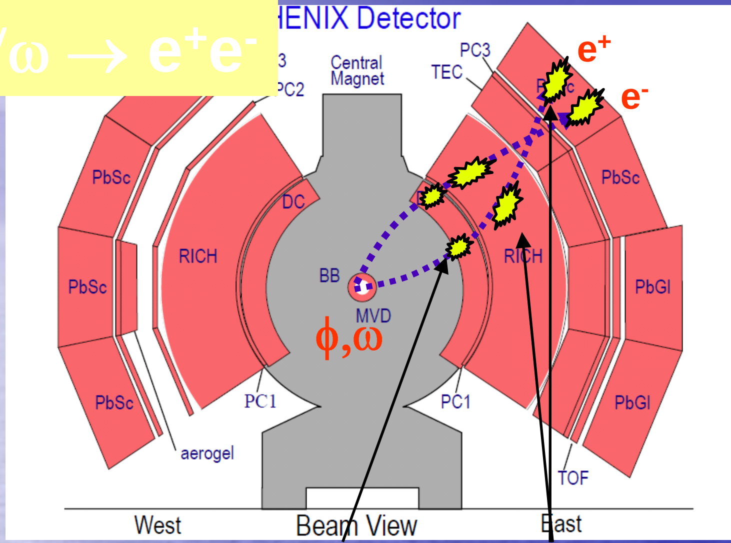
$$+ \int_0^{l/l_0} \exp\{-\frac{x}{l_0}\} d(\frac{x}{l_0})[1 - \int_0^{(l-x)/l_i} \exp\{-\frac{y}{l_i}\} d(\frac{y}{l_i})]) =$$

$$= B_i * (\frac{\exp\{-l / l_0\}}{1 - l_i / l_0} + \frac{\exp\{-l / l_i\}}{1 - l_0 / l_i}) \rightarrow$$

$$\rightarrow \{ {B_i (l_i \rightarrow \infty) \atop B_i * \exp\{-l / l_0\} (l_i \rightarrow 0)} \}$$

Electron, hadron and photon in PHENIX

$\phi/\omega \rightarrow e^+e^-$

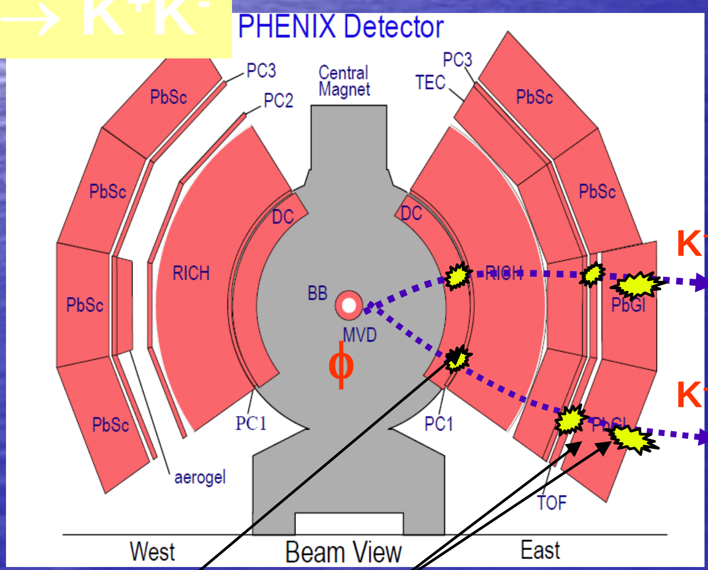


Momentum Electron ID

- PHENIX acceptance
  - $-0.35 < \eta < 0.35$
  - 2 x 90°in azimuthal angle for two arms
- Event selection
  - BBC

- Electron ID
  - RICH
  - EMCal
- photon ID
  - EMCal
- Hadron ID
  - TOF
  - EMCal-TOF

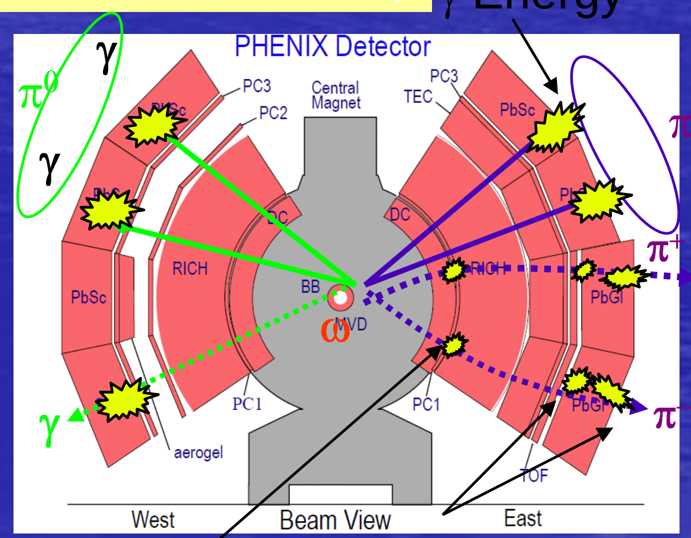
$\phi \rightarrow K^+K^-$



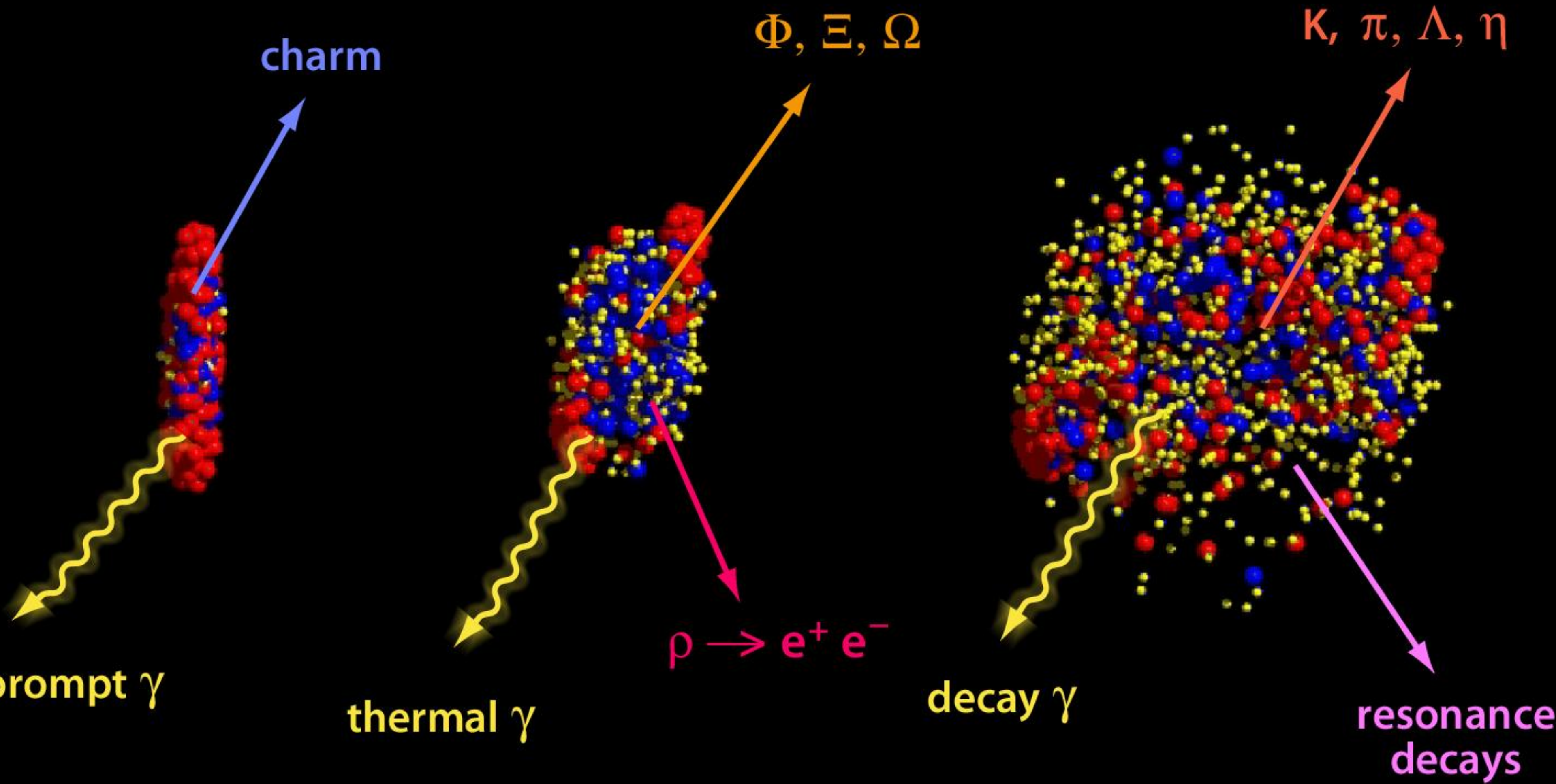
Momentum Hadron ID

$\omega \rightarrow \pi^+\pi^-\pi^0, \pi^0\gamma$

γ Energy



Momentum Hadron ID


charm
Φ, Ξ, Ω
K, π, Λ, η
rompt γ
thermal γ
ρ → e⁺ e⁻
decay γ
resonance
decays

Why φ ?(common part)

The ϕ –meson was proposed in the middle of 80'(Koch,Muller,Rafelski PR142,ShorPRL54) as one of the most promising QGP messengers because of the following reasons:

- **an enhancement of ϕ –meson, as well as other strange hadrons in QGP phase**
- **ϕ interaction cross section is small and ϕ will keep information about the early hot and dense phase**
- **ϕ meson spectrum is not distorted by feeddown from resonance decays**
- **strangeness local conservation for ϕ**